

CLAIM AMENDMENTS

Please cancel claims 1 – 19 and insert new claims 20 – 155 as follows:

20. (new) An optical identification element having a chemical attached thereto, comprising:
- a substrate;
  - at least a portion of said substrate having at least one diffraction grating disposed therein, said grating having a resultant refractive index variation at a grating location; and
  - said grating providing an output optical signal indicative of a code when illuminated by an incident light signal propagating in free space; and
  - the chemical being attached to at least a portion of said substrate.
21. (new) The apparatus of claim 20 wherein said refractive index variation comprises at least one refractive index pitch superimposed at said grating location.
22. (new) The apparatus of claim 20 wherein said refractive index variation comprises a plurality of refractive index pitches superimposed at said grating location.
23. (new) The apparatus of claim 20 wherein said substrate is made of a material selected from the group: glass, silica, plastic, rubber, and polymer.
24. (new) The apparatus of claim 20 wherein said code comprises a plurality of digital bits.
25. (new) The apparatus of claim 20 wherein said code comprises at least a predetermined number of bits, said number being: 3, 5, 7, 9, 10, 12, 14, 16, 18, 20, 24, 28, 30, 40, 50, or 100.
26. (new) The apparatus of claim 20 wherein said code comprises a plurality of bits, each bit having a plurality of states.
27. (new) The apparatus of claim 20 wherein said code comprises a plurality of bits, each bit having a corresponding spatial location and each bit in said code having a value related to the intensity of said output optical signal at the spatial location of each bit.
28. (new) The apparatus of claim 27 wherein the value of each bit corresponds to the magnitude of refractive index variation of a corresponding refractive index pitch in said grating.

29. (new) The apparatus of claim 20 wherein said code comprises a plurality of digital bits, each bit having a corresponding spatial location and each bit in said code having a binary value related to the intensity of said output optical signal at the spatial location of each bit.

30. (new) The apparatus of claim 29 wherein the value of each bit corresponds to the presence or absence of a corresponding refractive index pitch in said grating.

31. (new) The apparatus of claim 1 wherein said incident light comprises a single wavelength.

32. (new) The apparatus of claim 20 wherein said incident light comprises a plurality of wavelengths or a single wavelength scanned over a predetermined wavelength range.

33. (new) The apparatus of claim 32 wherein said code comprises a plurality of bits, and each bit in said code having a value related to the intensity of said output optical signal at a wavelength corresponding to each bit.

34. (new) The apparatus of claim 33 wherein the value of each bit corresponds to the magnitude of refractive index variation of a corresponding refractive index pitch in said grating.

35. (new) The apparatus of claim 32 wherein said code comprises a plurality of digital bits, and each bit in said code having a binary value related to the intensity of said output optical signal at the wavelength corresponding to each bit.

36. (new) The apparatus of claim 35 wherein the value of each bit corresponds to the presence or absence of a corresponding refractive index pitch in said grating.

37. (new) The apparatus of claim 20 wherein said substrate has a length that is less than about 500 microns.

38. (new) The apparatus of claim 20 wherein said substrate has a diameter that is less than about 125 microns.

39. (new) The apparatus of claim 20 wherein said substrate has a reflective coating disposed thereon.

40. (new) The apparatus of claim 20 wherein said substrate has a coating disposed on at least a portion of said substrate, at least a portion of said coating being

made of a material that allows sufficient amount of said incident light signal to pass through said material to allow detection of said code.

41. (new) The apparatus of claim 20 wherein said substrate has a coating material disposed on at least a portion of said substrate, said coating comprising a polymer.

42. (new) The apparatus of claim 20 wherein said substrate has a magnetic or electric charge polarization.

43. (new) The apparatus of claim 20 wherein said substrate has geometry having holes therein or protruding sections therein.

44. (new) The apparatus of claim 20 wherein at least a portion of said substrate has an end cross sectional geometry selected from the group: circular, square, rectangular, elliptical, clam-shell, D-shaped, and polygon.

45. (new) The apparatus of claim 20 wherein at least a portion of said substrate has a side view geometry selected from the group: circular, square, rectangular, elliptical, clam-shell, D-shaped, and polygon.

46. (new) The apparatus of claim 20 wherein at least a portion of said substrate has a 3-D shape selected from the group: a cylinder, a sphere, a cube, and a pyramid.

47. (new) The apparatus of claim 20 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said substrate has a plurality of grating regions.

48. (new) The apparatus of claim 20 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said grating region has a refractive index that is greater than that of said non-grating region.

49. (new) The apparatus of claim 20 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said grating region has a refractive index that is not greater than that of said non-grating region.

50. (new) The apparatus of claim 20 wherein said incident light is incident on said substrate along a longitudinal grating axis of said grating.

51. (new) The apparatus of claim 20 wherein said incident light is incident on said substrate at an angle to a longitudinal grating axis of said grating.

52. (new) The apparatus of claim 20 wherein said incident light comprises laser light.

53. (new) The apparatus of claim 20 wherein said grating is a thin grating or a blazed grating.

54. (new) The apparatus of claim 20 wherein said substrate comprises a plurality of said gratings.

55. (new) The apparatus of claim 20 wherein said substrate comprises a plurality of said gratings each at different locations within said substrate.

56. (new) The apparatus of claim 20 wherein said substrate comprises a particle or bead.

57. (new) The apparatus of claim 20 wherein said chemical comprises at least one gene, oligonucleotide, protein, antibody, peptide, amino acid, NDA, cDNA, RNA, nucleic acid oligomer, polymer, or biological cell, or portion thereof.

58. (new) An encoded particle having a chemical attached thereto, comprising:

a particle;

at least a portion of said particle having at least one diffraction grating disposed therein, said grating having a resultant refractive index variation at a grating location; and said grating providing an output optical signal indicative of a code when illuminated by an incident light signal propagating in free space; and the chemical being attached to at least a portion of said particle.

59. (new) The apparatus of claim 58 wherein said refractive index variation comprises at least one refractive index pitch superimposed at said grating location.

60. (new) The apparatus of claim 58 wherein said refractive index variation comprises a plurality of refractive index pitches superimposed at said grating location.

61. (new) The apparatus of claim 58 wherein said particle is made of a material selected from the group: glass, silica, plastic, rubber, and polymer.

62. (new) The apparatus of claim 58 wherein said code comprises a plurality of digital bits.

63. (new) The apparatus of claim 58 wherein said code comprises at least a predetermined number of bits, said number being: 3, 5, 7, 9, 10, 12, 14, 16, 18, 20, 24, 28, 30, 40, 50, or 100.

64. (new) The apparatus of claim 58 wherein said code comprises a plurality of bits, each bit having a plurality of states.

65. (new) The apparatus of claim 58 wherein said code comprises a plurality of bits, each bit having a corresponding spatial location and each bit in said code having a value related to the intensity of said output optical signal at the spatial location of each bit.

66. (new) The apparatus of claim 65 wherein the value of each bit corresponds to the magnitude of refractive index variation of a corresponding refractive index pitch in said grating.

67. (new) The apparatus of claim 58 wherein said code comprises a plurality of digital bits, each bit having a corresponding spatial location and each bit in said code having a binary value related to the intensity of said output optical signal at the spatial location of each bit.

68. (new) The apparatus of claim 67 wherein the value of each bit corresponds to the presence or absence of a corresponding refractive index pitch in said grating.

69. (new) The apparatus of claim 58 wherein said incident light comprises a single wavelength.

70. (new) The apparatus of claim 58 wherein said incident light comprises a plurality of wavelengths or a single wavelength scanned over a predetermined wavelength range.

71. (new) The apparatus of claim 70 wherein said code comprises a plurality of bits, and each bit in said code having a value related to the intensity of said output optical signal at a wavelength corresponding to each bit.

72. (new) The apparatus of claim 71 wherein the value of each bit corresponds to the magnitude of refractive index variation of a corresponding refractive index pitch in said grating.



73. (new) The apparatus of claim 70 wherein said code comprises a plurality of digital bits, and each bit in said code having a binary value related to the intensity of said output optical signal at the wavelength corresponding to each bit.

74. (new) The apparatus of claim 73 wherein the value of each bit corresponds to the presence or absence of a corresponding refractive index pitch in said grating.

75. (new) The apparatus of claim 58 wherein said particle has a length that is less than about 500 microns.

76. (new) The apparatus of claim 58 wherein said particle has a diameter that is less than about 125 microns.

77. (new) The apparatus of claim 58 wherein said particle has a reflective coating disposed thereon.

78. (new) The apparatus of claim 58 wherein said particle has a coating disposed on at least a portion of said particle, at least a portion of said coating being made of a material that allows sufficient amount of said incident light signal to pass through said material to allow detection of said code.

79. (new) The apparatus of claim 58 wherein said particle has a coating material disposed on at least a portion of said particle, said coating comprising a polymer.

80. (new) The apparatus of claim 58 wherein said particle has a magnetic or electric charge polarization.

81. (new) The apparatus of claim 58 wherein said particle has geometry having holes therein or protruding sections therein.

82. (new) The apparatus of claim 58 wherein at least a portion of said particle has an end cross sectional geometry selected from the group: circular, square, rectangular, elliptical, clam-shell, D-shaped, and polygon.

83. (new) The apparatus of claim 58 wherein at least a portion of said particle has a side view geometry selected from the group: circular, square, rectangular, elliptical, clam-shell, D-shaped, and polygon.

84. (new) The apparatus of claim 58 wherein at least a portion of said particle has a 3-D shape selected from the group: a cylinder, a sphere, a cube, and a pyramid.

85. (new) The apparatus of claim 58 wherein said particle has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said particle has a plurality of grating regions.

86. (new) The apparatus of claim 58 wherein said particle has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said grating region has a refractive index that is greater than that of said non-grating region.

87. (new) The apparatus of claim 58 wherein said particle has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said grating region has a refractive index that is not greater than that of said non-grating region.

88. (new) The apparatus of claim 58 wherein said incident light is incident on said particle along a longitudinal grating axis of said grating.

89. (new) The apparatus of claim 58 wherein said incident light is incident on said particle at an angle to a longitudinal grating axis of said grating.

90. (new) The apparatus of claim 58 wherein said incident light comprises laser light.

91. (new) The apparatus of claim 58 wherein said grating is a thin grating or a blazed grating.

92. (new) The apparatus of claim 58 wherein said particle comprises a plurality of said gratings.

93. (new) The apparatus of claim 58 wherein said particle comprises a plurality of said gratings each at different locations within said particle.

94. (new) The apparatus of claim 58 wherein said particle comprises a particle or bead.

95. (new) The apparatus of claim 58 wherein said chemical comprises at least one gene, oligonucleotide, protein, antibody, peptide, amino acid, NDA, cDNA, RNA, nucleic acid oligomer, polymer, or biological cell, or portion thereof.

96. (new) A method of reading an encoded optical identification element having a chemical attached thereto, comprising:

obtaining a substrate, at least a portion of which having at least one diffraction grating disposed therein, said grating having a resultant refractive index variation at a grating location;

attaching the chemical to at least a portion of said substrate;

illuminating said substrate with incident light propagating in free space, said substrate providing an output light signal indicative of a code; and

reading said output light signal and detecting said code therefrom.

97. (new) The method of claim 96 wherein said refractive index variation comprises at least one refractive index pitch superimposed at said grating location.

98. (new) The method of claim 96 wherein said refractive index variation comprises a plurality of refractive index pitches superimposed at said grating location.

99. (new) The method of claim 96 wherein said substrate is made of a material selected from the group: glass, silica, plastic, rubber, and polymer.

100. (new) The method of claim 96 wherein said code comprises a plurality of digital bits.

101. (new) The method of claim 96 wherein said code comprises at least a predetermined number of bits, said number being: 3, 5, 7, 9, 10, 12, 14, 16, 18, 20, 24, 28, 30, 40, 50, or 100.

102. (new) The method of claim 96 wherein said code comprises a plurality of digital bits, each bit having a corresponding spatial location and each bit in said code having a binary value related to the intensity of said output optical signal at the spatial location of each bit.

103. (new) The method of claim 102 wherein the value of each bit corresponds to the presence or absence of a corresponding refractive index pitch in said grating.

104. (new) The method of claim 96 wherein said incident light comprises a single wavelength.

105. (new) The method of claim 96 wherein said substrate has a coating disposed on at least a portion of said substrate, at least a portion of said coating being made of a material that allows sufficient amount of said incident light signal to pass through said material to allow detection of said code.



106. (new) The method of claim 96 wherein at least a portion of said substrate has a 3-D shape selected from the group: a cylinder, a sphere, a cube, and a pyramid.

107. (new) The method of claim 96 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said substrate has a plurality of grating regions.

108. (new) The method of claim 96 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said grating region has a refractive index that is greater than that of said non-grating region.

109. (new) The method of claim 96 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said grating region has a refractive index that is not greater than that of said non-grating region.

110. (new) The method of claim 96 wherein said incident light is incident on said substrate along a longitudinal grating axis of said grating.

111. (new) The method of claim 96 wherein said incident light is incident on said substrate at an angle to a longitudinal grating axis of said grating.

112. (new) The method of claim 96 wherein said grating comprises a thin grating.

113. (new) The method of claim 96 wherein said substrate comprises a plurality of said gratings.

114. (new) The method of claim 96 wherein said substrate comprises a particle or bead.

115. (new) The method of claim 96 wherein said chemical comprises at least one gene, oligonucleotide, protein, antibody, peptide, amino acid, NDA, cDNA, RNA, nucleic acid oligomer, polymer, or biological cell, or portion thereof.

116. (new) A method of reading an encoded particle having a chemical attached thereto, comprising:

obtaining a particle, at least a portion of which having at least one diffraction grating disposed therein, said grating having a resultant refractive index variation at a grating location;

attaching the chemical to at least a portion of said particle;

illuminating said particle with incident light, said particle providing an output light signal indicative of a code; and

reading said output light signal and detecting said code therefrom.

117. (new) The method of claim 116 wherein said refractive index variation comprises at least one refractive index pitch superimposed at said grating location.

118. (new) The method of claim 116 wherein said refractive index variation comprises a plurality of refractive index pitches superimposed at said grating location.

119. (new) The method of claim 116 wherein said particle is made of a material selected from the group: glass, silica plastic, rubber, and polymer.

120. (new) The method of claim 116 wherein said code comprises a plurality of digital bits.

121. (new) The method of claim 116 wherein said code comprises at least a predetermined number of bits, said number being: 3, 5, 7, 9, 10, 12, 14, 16, 18, 20, 24, 28, 30, 40, 50, or 100.

122. (new) The method of claim 116 wherein said code comprises a plurality of digital bits, each bit having a corresponding spatial location and each bit in said code having a binary value related to the intensity of said output optical signal at the spatial location of each bit.

123. (new) The method of claim 122 wherein the value of each bit corresponds to the presence or absence of a corresponding refractive index pitch in said grating.

124. (new) The method of claim 116 wherein said incident light comprises a single wavelength.

125. (new) The method of claim 116 wherein said substrate has a coating disposed on at least a portion of said substrate, at least a portion of said coating being made of a material that allows sufficient amount of said incident light signal to pass through said material to allow detection of said code.

126. (new) The method of claim 116 wherein at least a portion of said substrate has a 3-D shape selected from the group: a cylinder, a sphere, a cube, and a pyramid.

127. (new) The method of claim 116 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said substrate has a plurality of grating regions.

128. (new) The method of claim 116 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said grating region has a refractive index that is greater than that of said non-grating region.

129. (new) The method of claim 116 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said grating region has a refractive index that is not greater than that of said non-grating region.

130. (new) The method of claim 116 wherein said incident light is incident on said substrate along a longitudinal grating axis of said grating.

131. (new) The method of claim 116 wherein said incident light is incident on said substrate at an angle to a longitudinal grating axis of said grating.

132. (new) The method of claim 116 wherein said grating comprises a thin grating.

133. (new) The method of claim 116 wherein said substrate comprises a plurality of said gratings.

134. (new) The method of claim 116 wherein said substrate comprises a particle or bead.

135. (new) The method of claim 116 wherein said chemical comprises at least one gene, oligonucleotide, protein, antibody, peptide, amino acid, NDA, cDNA, RNA, nucleic acid oligomer, polymer, or biological cell, or portion thereof.

136. (new) A method of performing a multiplexed particle assay, comprising:  
obtaining a plurality of particles each having at least one diffraction grating disposed therein, said grating having a resultant refractive index variation at a grating location;

attaching at least one probe to at least one of said particles, thereby providing functionalized particles;

placing said functionalized particles in contact with at least one analyte, said analyte having a corresponding label disposed thereon;

illuminating said particles with at least one incident light, said particle providing a first output light signal indicative of a code and a second output light signal indicative of said label;

reading said first output light signal and detecting said code therefrom; and

reading said second output light signal and detecting said label therefrom.

137. (new) The method of claim 136 wherein said refractive index variation comprises at least one refractive index pitch superimposed at said grating location.

138. (new) The method of claim 136 wherein said refractive index variation comprises a plurality of refractive index pitches superimposed at said grating location.

139. (new) The method of claim 136 wherein said particle is made of a material selected from the group: glass, silica, plastic, rubber, and polymer.

140. (new) The method of claim 136 wherein said code comprises a plurality of digital bits.

141. (new) The method of claim 136 wherein said code comprises at least a predetermined number of bits, said number being: 3, 5, 7, 9, 10, 12, 14, 16, 18, 20, 24, 28, 30, 40, 50, or 100.

142. (new) The method of claim 136 wherein said code comprises a plurality of digital bits, each bit having a corresponding spatial location and each bit in said code having a binary value related to the intensity of said output optical signal at the spatial location of each bit.

143. (new) The method of claim 142 wherein the value of each bit corresponds to the presence or absence of a corresponding refractive index pitch in said grating.

144. (new) The method of claim 136 wherein said incident light comprises a single wavelength.

145. (new) The method of claim 136 wherein said substrate has a coating disposed on at least a portion of said substrate, at least a portion of said coating being

made of a material that allows sufficient amount of said incident light signal to pass through said material to allow detection of said code.

146. (new) The method of claim 136 wherein at least a portion of said substrate has a 3-D shape selected from the group: a cylinder, a sphere, a cube, and a pyramid.

147. (new) The method of claim 136 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said substrate has a plurality of grating regions.

148. (new) The method of claim 136 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said grating region has a refractive index that is greater than that of said non-grating region.

149. (new) The method of claim 136 wherein said substrate has a grating region where said grating is located and a non-grating region where said grating is not located; and wherein said grating region has a refractive index that is not greater than that of said non-grating region.

150. (new) The method of claim 136 wherein said incident light is incident on said substrate along a longitudinal grating axis of said grating.

151. (new) The method of claim 136 wherein said incident light is incident on said substrate at an angle to a longitudinal grating axis of said grating.

152. (new) The method of claim 136 wherein said grating comprises a thin grating.

153. (new) The method of claim 136 wherein said substrate comprises a plurality of said gratings.

154. (new) The method of claim 136 wherein said substrate comprises a particle or bead.

155. (new) The method of claim 136 wherein said chemical comprises at least one gene, oligonucleotide, protein, antibody, peptide, amino acid, NDA, cDNA, RNA, nucleic acid oligomer, polymer, or biological cell, or portion thereof.